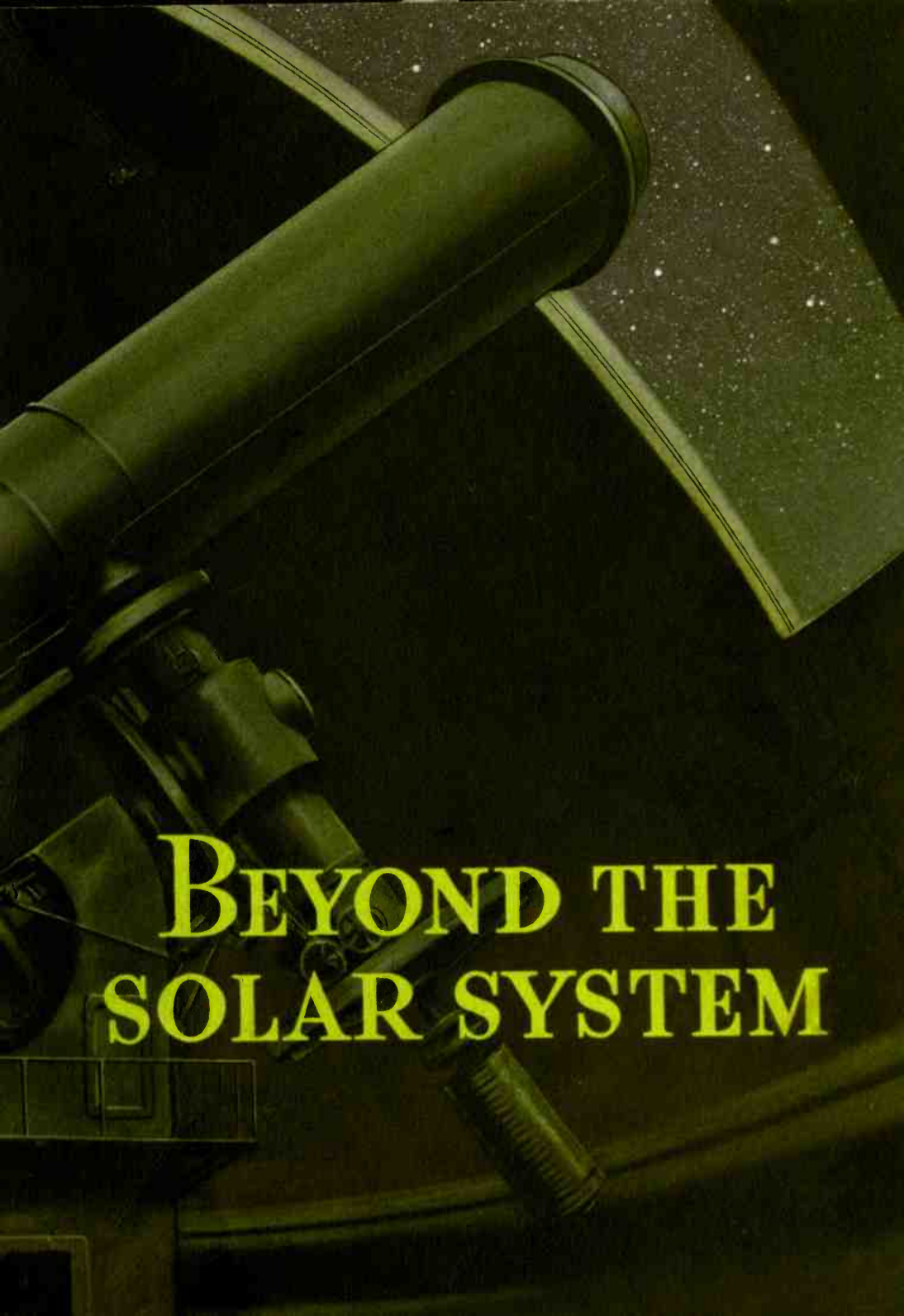
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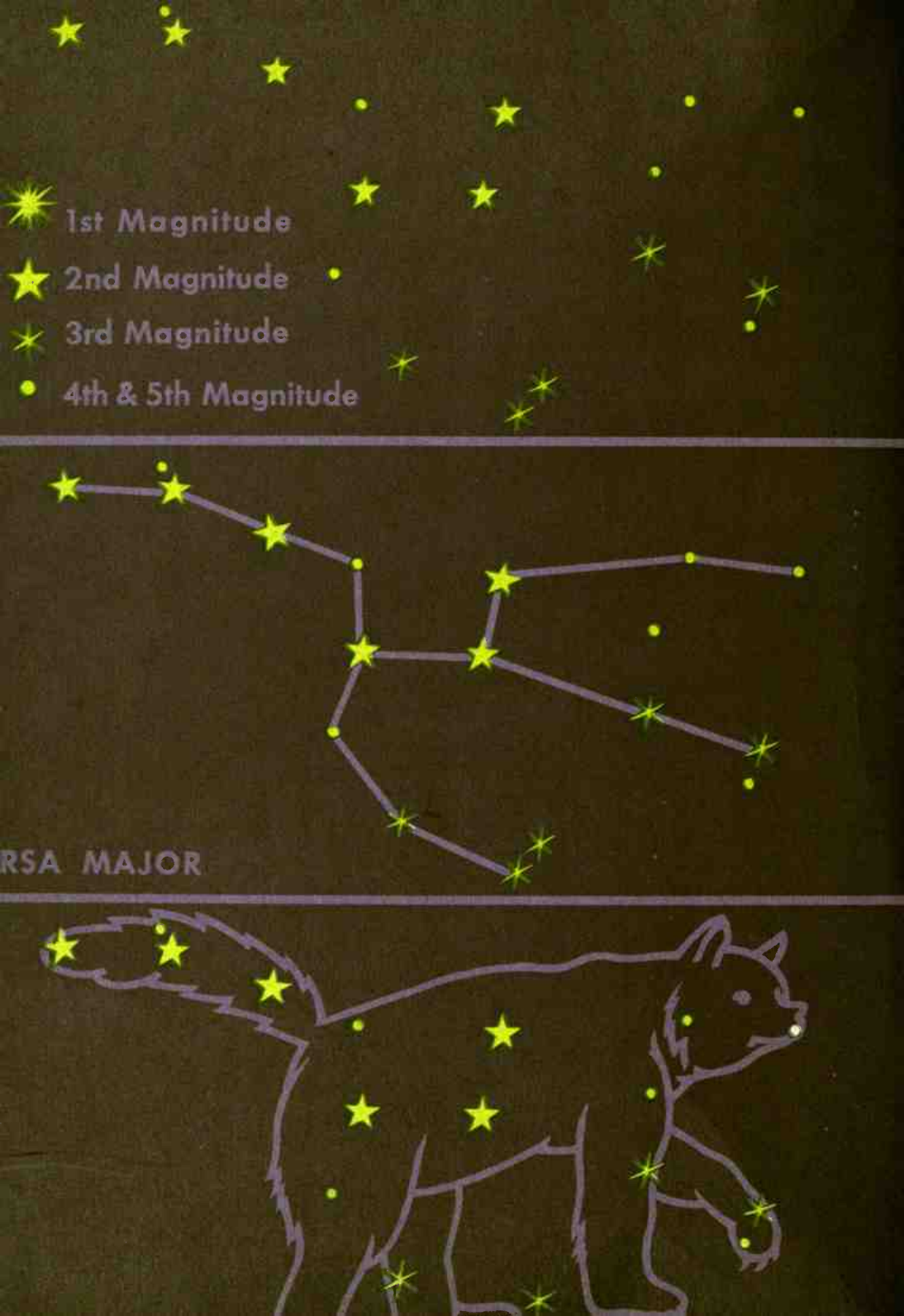
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RSA MAJOR

THE BASIC SCIENCE EDUCATION SERIES

BEYOND THE SOLAR SYSTEM

By

BERTHA MORRIS PARKER
LABORATORY SCHOOL, UNIVERSITY OF CHICAGO

Checked for Scientific Accuracy by
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Yerkes Observatory

Junior High

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Beyond the Solar System

Twinkle, twinkle, little star,
How I wonder what you are,
Up above the world so high,
Like a diamond in the sky.

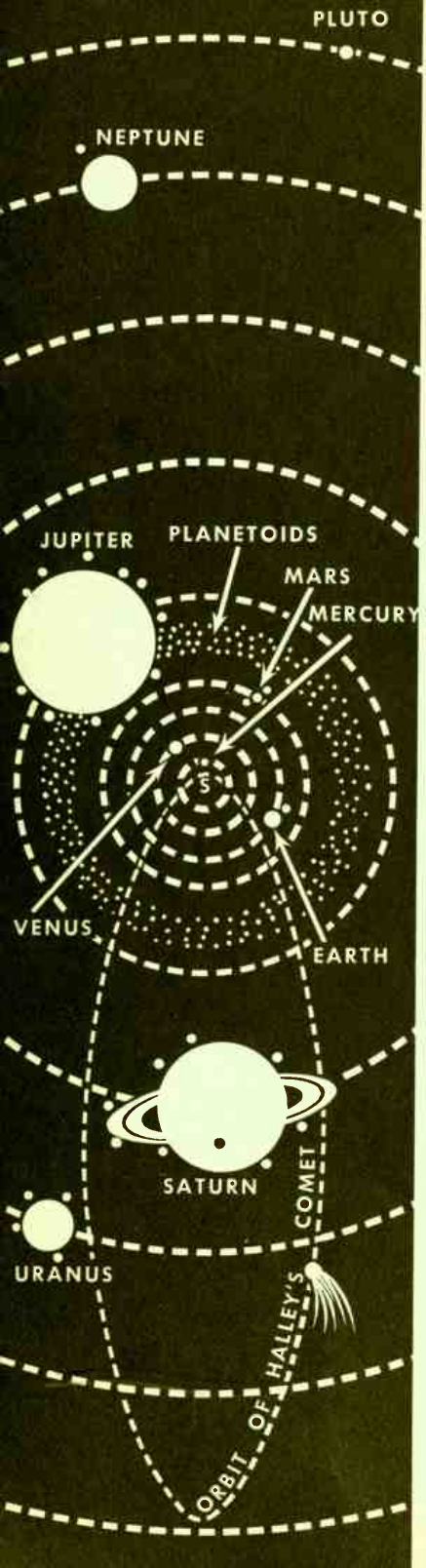
THIS jingle probably seems to you very much out of date. You are almost sure to know that stars are suns. But the jingle is not so much out of date as it at first seems to be. Even now you may well wonder when you see a star in the sky what it is. For, although all stars are suns, they are not all single suns. The star you see twinkling may be a double star—two stars traveling around and around each other. Each of the stars in a double star may be a double star. A single twinkling point of light in the sky may, then, be two or four suns instead of one. A star may even be six suns traveling around one another.

Astronomers have already discovered with their telescopes more than 17,000 double stars. About one out of every five of the stars you see when you look up at the sky is a double star.

Studying the distant suns that twinkle in the sky is, you will find, a great strain on the imagination. If you are to get a true picture of the stars, you will have to imagine temperatures so high that the temperature in the center of a furnace fire would be cool beside them. You will have to imagine distances so great that the distance from the earth to our sun seems only a step. You will have to imagine sizes so large that they make the earth seem a mere speck. You will have to imagine, too, periods of time so long that a hundred years seems to be no time at all.

The Great Spiral Nebula in Andromeda

Courtesy of the Yerkes Observatory and the University of Chicago Press



Seeing Stars

There are stars in all directions from the earth. The only reason we do not see stars in the daytime is that the sunlit air hides them. The air scatters the light of the sun over the whole sky. If we could go up above the air, the sky would be black and we would see stars both night and day.

Of course, there is one star that we can see only in the daytime—our sun. Our sun is a star just as the other stars are suns. The two words "sun" and "star" mean the same thing. When we talk about the stars, however, we usually mean all the stars except the sun. In this book "stars" is used as a "shorthand" way of saying "stars other than the sun."

Sometimes we call heavenly bodies "stars" which are not really stars. Falling stars, or shooting stars, are not true stars. They are tiny bits of stone or iron, most of them no larger than a pea, which become white-hot when they fall through our air toward the earth. They are not at all like suns. "Meteors" is a better name for them than "falling stars" or "shooting stars."

The heavenly bodies we call the "evening stars" and the "morning stars" are not true stars either. They are planets instead. The earth is a planet. Circling around the sun there are eight other large planets. Two of them cannot be seen without a telescope—they are too far away. The others look like stars when we see them

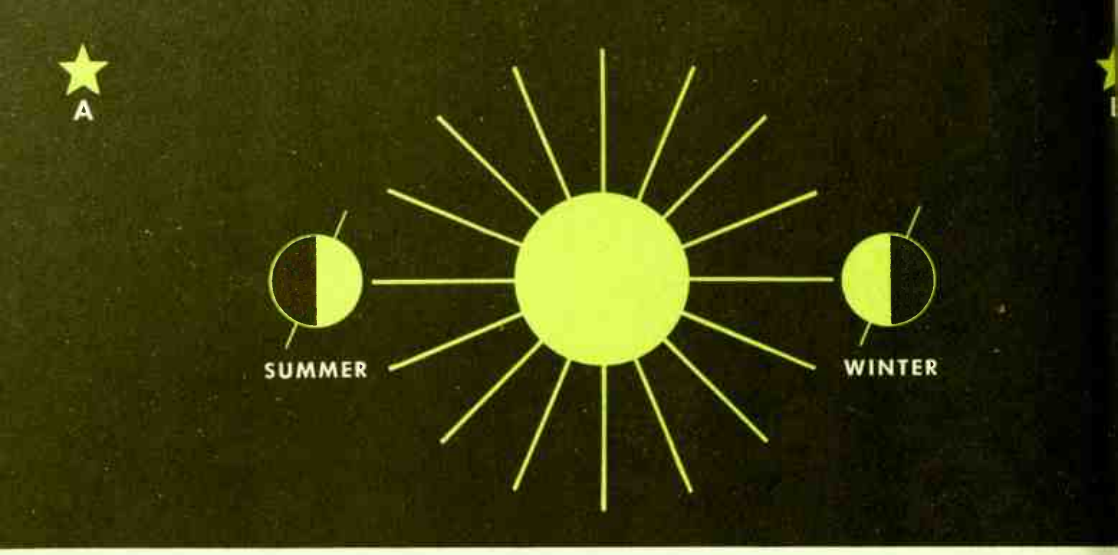
in the sky—some of them like very brilliant stars. When we see a planet shining brightly in the west soon after sunset, we call it an "evening star." When we see a planet shining in the eastern sky just before sunrise, we call it a "morning star." Planets are really very different from true stars. They do not give off any light of their own. They shine only because they reflect some of the sunlight that falls on them.

Traveling around the sun there are not only nine large planets—there are also more than a thousand very small planets. There are, too, millions of meteors and hundreds of those queer heavenly bodies called comets. Besides, most of the large planets have moons traveling around them as they travel around the sun. The sun and all the heavenly bodies that travel around it make up the *solar system.* The solar system is very large. But when we look at the stars, we are looking far, far *beyond the solar system.*

The earth is about 93 million miles from the sun. Pluto, which, so far as anyone knows, is the outermost planet in the solar system, is about 40 times as far away from the sun as we are. Pluto is so far away from the sun and from us that we cannot see it without a very powerful telescope. The distance from the sun to Pluto, however, is very short as compared with the distance to even the nearest star. The distance from the sun to the nearest star is about 7,000 times as great as the distance from the sun to Pluto. If the stars were not great suns, we could not see them at all.

What stars you can see when you look up at the sky on a clear night depends chiefly on three things: where you are on the earth, where the earth is in its path around the sun, and what time of night it is when you are looking at the sky.

Some stars can never be seen from some parts of the earth; others can never be seen from other parts of the earth. The diagram on this page will help you see why. Star A could never be seen from far south of the Equator. In the



same way, Star B could never be seen from the Far North. In both cases the earth itself shuts off the view of the star. Only from the Equator can all the stars be seen. Of course, even there only about half—really somewhat less than half—of the stars can be seen at any one time.

Because of the turning of the earth on its axis, the night sky is never the same for any two minutes in succession. The turning of the earth makes the stars appear to move in the sky. A star which is above our heads at midnight is low in the western sky five hours later, and stars that could not be seen at midnight have come into view in the eastern sky.

The diagram on this page helps explain how the place of the earth in its path around the sun is important in determining what stars you see when you look up at the sky. During the summer, if you were in the United States, Star A would be high in the sky at midnight. During the winter it would be high in the sky at noon. Of course, at noon the star would be lost in the glare of the sun. In the same way, Star B would be high in the sky at midnight in the winter and high in the sky at noon during the summer.

Do you see now why we need maps of the sky to help us locate stars? Do you see, too, why every map of the sky is made for a certain place on the earth and for a certain time of the night and the year?

Sky Distances

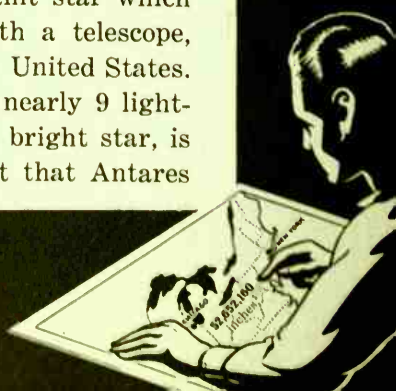
If you were trying to tell someone how far it is from Chicago to New York, you would not tell them the distance in inches. "It is much easier to understand 831 miles than 52,652,160 inches." In the same way, it is foolish to try to measure the distance of the stars from us in miles. All the stars are so far away that, if the distances were measured in miles, the numbers would be so big that they would not mean much. We have to use a longer measure.

One of the measures astronomers use is the *light-year*. A light-year is the distance light travels in one year. When a scientist tells us that a star is 200 light-years away, he means that it is so far away that its light has to travel for 200 years in order to reach us.

We sometimes measure distances on the earth in much the same way. You might say, for example, that you live ten minutes by bus from school. You mean that you can travel in a bus from your home to your school in ten minutes. Anyone who knows how fast a bus travels will have a good idea of the distance from your home to your school.

Light travels at the enormous speed of 186,000 miles a second. If you wish to find out for yourself how many miles there are in a light-year, you have only to multiply 186,000 by 60 (the number of seconds in a minute), then by 60 (the number of minutes in an hour), then by 24 (the number of hours in a day), and then by 365¼ (the number of days in a year). You will find that your result has thirteen figures in it. In round numbers a light-year is six million million miles.

Proxima Centauri is our nearest star neighbor. This star is about 4¼ light-years away. It is a very faint star which cannot be seen without a telescope. Even with a telescope, it can never be seen in the northern half of the United States. Sirius, the brightest star in the whole sky, is nearly 9 light-years away. Antares (an-tā′rēz), another very bright star, is 400 light-years distant. Suppose for a moment that Antares



has an inhabited planet like the earth. Suppose, too, that the people on the planet have telescopes so powerful that they can see happenings on the earth. Then they are just now seeing what happened here about fifty years after Columbus discovered America. You cannot see an object unless light from it reaches your eyes. None of the sunlight which fell on Columbus as he stepped ashore in America reached Antares until the year 1892.

Even Antares is close to us as compared with some stars. The picture on page 2 shows a great star city, or collection of stars. This star city is nearly a million light-years away! Other star cities are more than 100 million light-years from us. The light which reaches our eyes from the distant star cities tonight left them long, long before there were any civilized people on the earth—in some cases before there were any people on the earth at all.

How Many Stars Are There?

When you look up at the sky on a clear night, you see so many stars that they seem countless. Those you see are not really countless. Of course, not all people see the same number of stars. Some people have better eyes than others. If you have very good eyes, you probably see about 3,000.

If you use a telescope, you can see thousands more. The more powerful the telescope, the more stars you are able to see.

In taking pictures of the stars, an astronomer can easily vary the length of time he exposes the plate of his camera. A long exposure as a rule shows many stars which a short exposure does not show. The two pictures on page 10 were taken through the same telescope. They are pictures of exactly the same part of the sky. It is a part of the sky in which there are no stars which are bright enough to be seen without a telescope. The right-hand picture on page 10 shows what a mistake it would be to think that there are no stars in that part of the sky.

Our sun is one star in a tremendous star city much like the star city pictured on page 2. Scientists are sure that there are at least 40,000 million stars in our star city. There may be thousands of millions more.

Perhaps "40,000 million stars" will mean more to you if you know how long it would take you to count so many. If you counted them at the rate of 100 a minute (you would do well if you could count them so fast), you would have to keep on counting day and night for nearly 800 years.

Now that you have some idea of the number of stars in our star city, your imagination must be stretched again.

Two Pictures of the Same Part of the Sky
Courtesy of Mount Wilson Observatory

There are more than three million other star cities. You can see that counting all the stars in the whole universe would be about like counting every grain of sand on every seashore in the world.

Groups of Stars

The stars which are bright enough to be seen without a telescope are not scattered evenly across the sky. Instead, they are arranged in groups called *constellations*. The word "constellation" comes from two Latin words. One of them, *stella,* means "star," and the other, *con,* means "together."

The people of olden times imagined that each group of stars they saw was a picture of something or somebody. To them the sky was a great picture-book. Many of the people of early days were shepherds, and, as they watched their flocks at night, they learned to know the groups of stars better than most of us do now.

Most of the names of the constellations are Latin or Greek names. We can tell from the meanings of these names what pictures the people of olden times saw in the sky, but it is very hard for us to see some of these pictures.

Probably the best known of all the constellations is Ursa Major—"The Great Bear." The seven brightest stars in this constellation make the Big Dipper. This constellation has

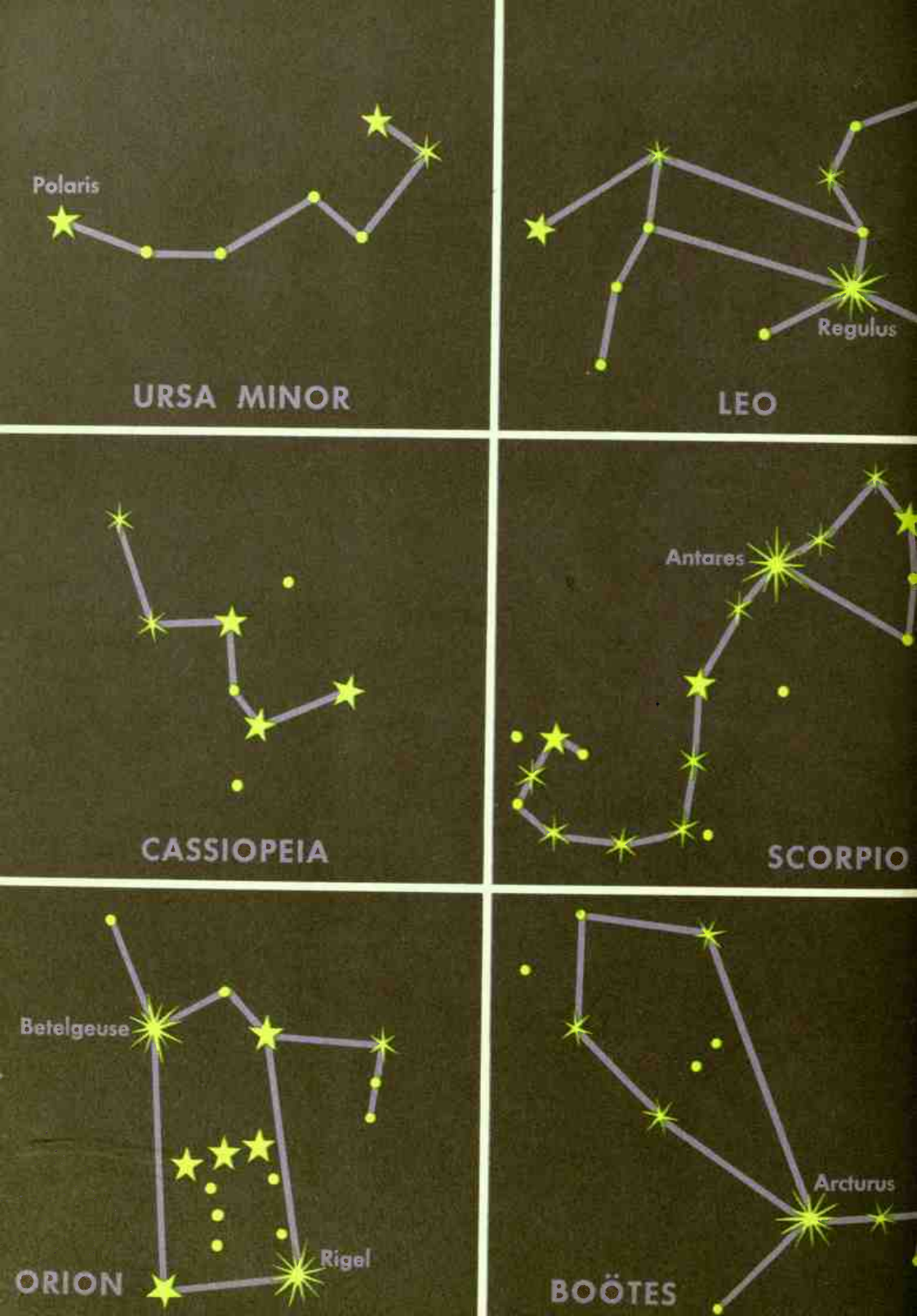
had many different names in its history. Different people have seen in it different pictures. The Italians still call it "The Car of Boötes"; the Scandinavians call it "Thor's Chariot"; and the Welsh and the Irish call it "The Chariot of King Arthur." To many English people the Great Bear is "The Plough." The Pawnee Indians thought that the stars of the bowl of the Dipper were a sick man on a stretcher and that the first star in the handle of the Dipper was the medicine man following the bier.

Queerly enough, many peoples far away from one another have seen in the constellation the picture of a bear. The Finns, the Iroquois Indians, and the Greeks are among them. In the Middle Ages in Europe, the constellation was often pointed out to children as one of the bears that ate up the boys who made fun of the prophet Elisha. Some writers believe that people of long ago thought this constellation was a bear because it is in the northern sky (bears can live in the Far North) and because it "prowls" along its path slowly.

Two of the stars of the Big Dipper are on a line with the North Star. They are often called "the pointers," because they help locate the North Star. The North Star is not one of the brightest stars, and it is not always easy to find. The pointers are a real help. The distance to the North Star from the pointer nearest it looks to be about five times the distance between the pointers.

One of the stars in the handle of the Dipper has a companion star named Alcor. Only people with at least fairly good eyesight can see Alcor. Some scientists think that its name comes from an Arab word meaning "the test." At any rate, people sometimes test their eyesight by trying to see Alcor on a clear night.

Ursa Minor ("The Little Bear") we usually call "The Little Dipper." It has in it the North Star—the most important star in the whole sky. This star is at the very end of the tail of the Little Bear, or the handle of the Little Dipper. Ursa Minor has been called, among many other things, a bier, a wagon, a throne, a heavenly mountain, and a small chariot.


Polaris
URSA MINOR
Regulus
LEO
CASSIOPEIA
Antares
SCORPIO
Betelgeuse
Rigel
ORION
Arcturus
BOÖTES

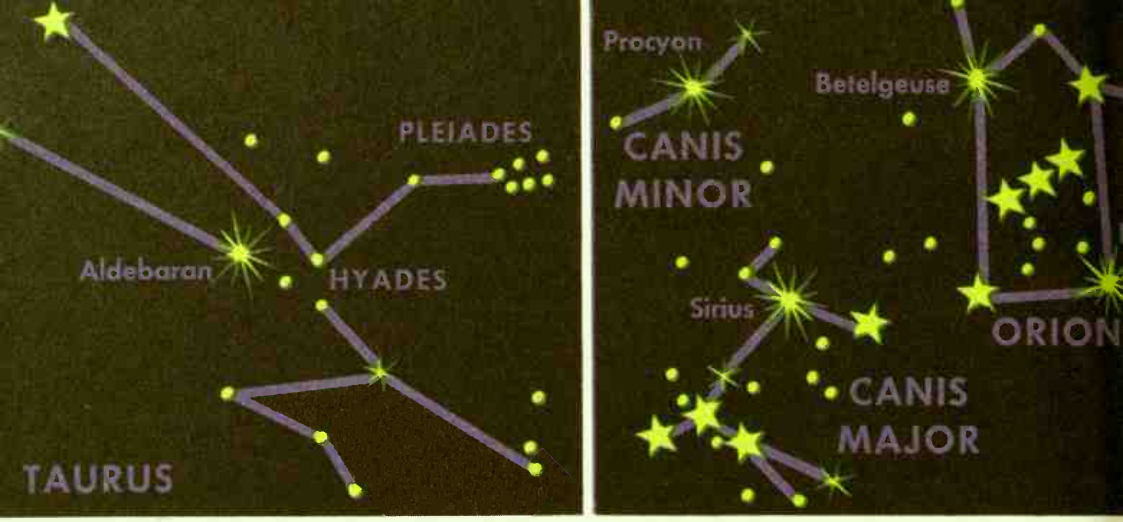
Cassiopeia ("The Woman in the Chair") is not far from the North Star. It is on the opposite side of the North Star from the Big Dipper. Six of the stars of this constellation make a *W*. The *W* does look a little like a chair, and the people of long ago thought that the stars close by showed a woman sitting in the chair.

Orion ("The Hunter") is the brightest constellation in the sky. You will never have any trouble finding Orion if it is above the horizon. You can find it easily from the row of three bright stars which makes Orion's belt. Nowhere else in the sky is there such a row. Running down from the belt, there is another row of stars which makes the Hunter's sword. After you have found the belt, you can easily find the stars which mark the Hunter's right shoulder, left shoulder, right knee, and left foot. These four stars make a great rectangle in the sky. The right-shoulder star, Betelgeuse (bet'el-gūz), and the left-foot star, Rigel (rī'gel), are among the brightest stars in the sky. In our part of the earth, Orion is a southern constellation and can be seen early in the evening in the winter months.

Almost all peoples have seen a hunter or a warrior in this great constellation. The Chinese, however, call it a tiger, and the Eskimos think that the three stars of the belt are three steps cut in a great heavenly snowdrift.

Not far from Orion are the two constellations of Canis Major ("The Great Dog") and Canis Minor ("The Little Dog"). Canis Major has in it the brightest star in the whole sky—Sirius. Sirius is commonly called "The Dog Star." It is on a line with the stars of Orion's belt. Canis Minor has a very bright star in it, too—Procyon (prō'si-on). It is easy to understand why, since ancient people made a hunter out of one group of stars, they called some of the smaller constellations close by "dogs."

Taurus ("The Bull"), not far from Orion in the sky, has in it one very bright red star—Aldebaran (al-deb'a-ran). It has also two small groups of stars called "The Pleiades" (plē'a-dēz) and "The Hyades" (hī'a-dēz).



Almost everyone knows the Pleiades. We find many mentions of the Pleiades in the writings of the people of olden times. The Greeks thought of them as "The Seven Sisters," the ancient Babylonians called them "The Many Little Ones," and they are "The Little Eyes" to the savage tribes of the South Pacific islands. Some tribes of North American Indians considered them seven brothers, while other tribes thought of them as seven beautiful maidens.

There are six easily seen stars in the group. On a clear night a person with good eyes can see a seventh. Some people are even able to see eleven stars in the group.

Some primitive peoples still measure their year by the Pleiades. The year begins when the Pleiades are in a certain position at a certain time of night. The year ends and a new year begins when the Pleiades are in the same place in the sky at the same time of night. In ancient Persia on the day each year when the Pleiades were in a certain position, no petition was presented to the king in vain.

The picture on page 21 is a picture of the Pleiades taken through a telescope. Notice that the picture shows many stars besides the brightest six. Even with a small telescope, about a hundred stars can be seen in this group.

The Hyades used to be called "The Rainy Hyades" by the Greeks. When they were in a certain position, they were supposed to bring rain.

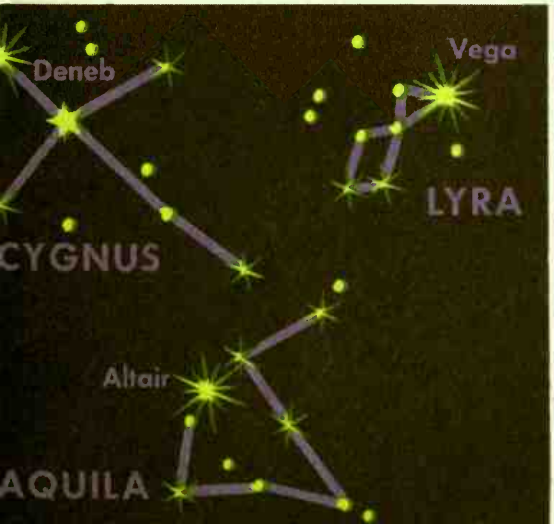
Early in the night in our summer there are three bright stars that make a big triangle in the sky. They are Vega, Deneb, and Altair. If you find one of these stars, it will be easy for you to find the other two.

Vega is a bluish-white star. It is very bright. Vega is the only bright star in the constellation Lyra ("The Lyre"). Deneb is in Cygnus ("The Swan"). Sometimes this constellation is called "The Northern Cross." Altair is in Aquila ("The Eagle").

On page 12 and on the inside back cover there are maps of six other constellations. Each of these constellations except Pegasus (peg'a-sus) has one very bright star in it. The bright stars help you find the constellations in which they are. Pegasus is easy to find because of its shape.

Arcturus, you can see from the maps, is a bright star in Boötes ("The Hunter"). When a world's fair was held in Chicago in 1933, the light from Arcturus was made to turn on the lights of the fair on each clear night. The light shone down through a telescope to an electric eye, and the electric eye turned on the lights of the fairgrounds. Of course, on a cloudy night the lights had to be turned on in another way.

If you could see the stars during the daytime, the sun would appear to be in first one group of stars and then another. It would seem to move from one group of stars to another because of the traveling of the earth around the sun. When the earth is opposite the sun from Cancer ("The



Crab"), the sun would look to be in Cancer. The stars of Cancer would rise and set with the sun. A month later the sun would look to be in Leo ("The Lion"). The stars in Leo would then rise and set with the sun.

The "street" along which the sun seems to move among the stars is called the *zodiac*. The twelve constellations pictured on pages 18 and 19 lie along this "street." The word "zodiac" means "animal circle"—all twelve constellations of the zodiac were first named for animals.

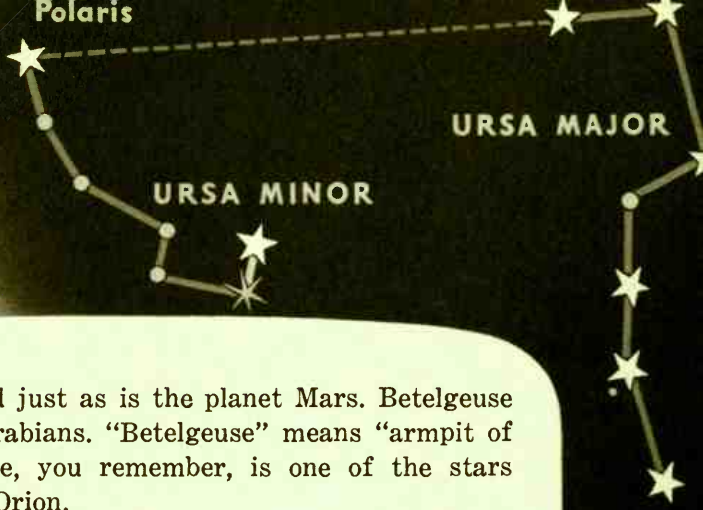
Leo, Virgo, Taurus, and Scorpio (pages 12, 14, and the inside back cover) are easy to find in the sky because of their bright stars. Most of the other constellations of the zodiac are rather hard to find. Of course, we cannot see a constellation of the zodiac when the sun is between us and the constellation. But at some time of the year each constellation of the zodiac is visible in the early night sky.

On large star maps you can find other constellations that are visible in our sky. Star maps for the Southern Hemisphere would, of course, show constellations that we in the Northern Hemisphere can never see.

Naming the Stars

Many of the big buildings in our cities have names. They have such names as "Board of Trade Building," "Union Station," and "Merchandise Mart." Other big buildings are called simply by their addresses. For example, "Five Thousand East End Avenue" and "333 North Michigan" are the only names the buildings at those addresses in Chicago have. In the same way, some stars have names of their own. Others have simply "sky addresses."

About fifteen stars have been called by name in the earlier pages of this book. Among them are Sirius, Antares, and Betelgeuse. Between forty and fifty stars have such names. These stars were named by the people of ancient times. Sirius was named by the Greeks. Its name means "sparkling." Sirius, as you have been told, is the brightest star in the sky. "Antares" is also a Greek name. It means "rival of



Mars." Antares is red just as is the planet Mars. Betelgeuse was named by the Arabians. "Betelgeuse" means "armpit of the giant." Betelgeuse, you remember, is one of the stars in the constellation Orion.

The third brightest star in the sky is Alpha Centauri, a star which can never be seen in the northern part of the United States. "Alpha Centauri" is a "sky-address" name. "Centauri" shows that the star belongs in the constellation Centaurus. "Alpha" is the first letter of the Greek alphabet. As a rule, the brightest star of a constellation is called "Alpha," the second brightest "Beta" (the second letter of the Greek alphabet), the third brightest "Gamma" (the third letter of the Greek alphabet), and so on. Alpha Centauri is the brightest star in Centaurus. If you were looking in the sky for Beta Lyrae, you would look for the second brightest star in the constellation Lyra.

If the twenty-four letters of the Greek alphabet run out before all the stars of a constellation are named, Roman letters are used for the other stars of the constellation. If there are not enough Roman letters, numbers are used. One star, for instance, is called "27 Canis Major."

Of course, all the stars that have names of their own have sky addresses, too. Vega, the brightest star of the constellation Lyra, can be called "Alpha Lyrae." In the same way, Sirius can be called "Alpha Canis Majoris."

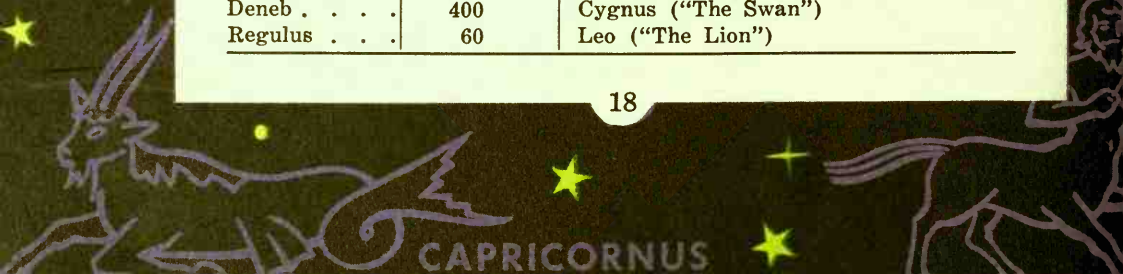
Some stars do not even have sky-address names. Stars so faint that they are hard to see through the best telescopes are often called by their numbers in some astronomer's catalogue of the stars. Wolf 457, for instance, is the star numbered 457 in the astronomer Wolf's catalogue.

The Twenty Brightest Stars

The brightness of a star, as we see it in the sky on a clear night, depends on how far away the star is and how much light it is giving off. Some stars are hundreds of light-years away but are bright because they are giving off tremendous amounts of light. Antares, for example, is 400 light-years away, but it shines brightly in our sky because it is a very, very large and brilliant sun. Sirius, the brightest star in the whole sky, is not nearly so huge a sun as Antares and does not give off nearly so much light, but it is much closer to us.

Sirius and Antares are both among the twenty brightest stars as we see them from the earth. The twenty brightest stars are often called *first-magnitude stars*. In the following list the first-magnitude stars are arranged in the order of their brightness as we see them. Many of these stars, you will notice, have been mentioned on earlier pages.

Star	Distance in Light-Years	Constellation
Sirius	8.8	Canis Major ("The Great Dog")
Canopus	200	Argo ("The Ship")
Alpha Centauri	4.3	Centaurus ("The Centaur")
Vega	26	Lyra ("The Lyre")
Capella	50	Auriga ("The Chariot")
Arcturus	40	Boötes ("The Hunter")
Rigel	600 (?)	Orion ("The Hunter")
Procyon	10.4	Canis Minor ("The Little Dog")
Achernar	70	Eridanus ("The River")
Beta Centauri	90	Centaurus ("The Centaur")
Altair	16	Aquila ("The Eagle")
Betelgeuse	300	Orion ("The Hunter")
Alpha Crucis	100	Crux ("The Cross")
Aldebaran	60	Taurus ("The Bull")
Pollux	32	Gemini ("The Twins")
Spica	200	Virgo ("The Virgin")
Antares	400	Scorpio ("The Scorpion")
Fomalhaut	24	Piscis Australis ("The Southern Fish")
Deneb	400	Cygnus ("The Swan")
Regulus	60	Leo ("The Lion")



Of course, you can never see all of these stars in the sky at one time. Some of them shine in the evening sky only at one time of year, others only at another time of year. Several, if you live in the northern part of the United States, you would have to go far to the south to see. Others cannot be seen from the far south.

The stars that are not first-magnitude stars are classified into other magnitudes according to their brightness. The North Star is a second-magnitude star. Second-magnitude stars are not so bright as first-magnitude stars but are brighter than those of the third magnitude. Six of the stars in the Big Dipper are second-magnitude stars. The seventh star of the Big Dipper is a fourth-magnitude star. The left-hand picture on page 10 shows all the stars down to the twelfth magnitude in the part of the sky toward which the camera was pointed. The right-hand picture shows all the stars down to the twentieth magnitude. Remember that these pictures were taken through a telescope. Without a telescope almost no one can see stars that are fainter than magnitude 6. The average brightness of the sixth-magnitude stars is only about one-hundredth the average brightness of the first-magnitude stars.

The Polestar

As you have already been told, the *North Star,* or *Polaris,* is the most important star in the sky. It has guided millions of travelers in their journeys on land and sea. Not only can you tell directions from this star, but you can also tell from it how far north of the Equator you are. The farther north you are, the higher the North Star is in the northern sky. South of the Equator, the North Star cannot serve as a guide because it cannot be seen.

The North Star is often called "the polestar" because the earth's axis is pointed almost exactly toward it. If you were standing at the North Pole, the North Star would be almost exactly above your head.

The rising and setting of the stars is caused by the turning of the earth on its axis. Since, as the earth spins around, its axis is pointed toward the North Star, this star does not rise or set. It is always at almost exactly the same place in the sky when seen from any one place on the earth. Since it is not exactly above the North Pole, it does not stay in exactly the same place. It traces a tiny circular path in the sky.

Queerly enough, Polaris has not always been the polestar. The earth's axis is very slowly changing its direction. At the time when the great pyramids in Egypt were being built, Thuban, one of the stars in the constellation of Draco ("The Dragon"), was the polestar. About 12,000 years from now, Vega, one of the first-magnitude stars, will be the polestar.

No matter where you are in our country, there are some stars besides the North Star that do not rise or set. The farther north you are, the more stars there are that never disappear below the horizon. The turning of the earth on its axis makes these stars seem to travel each day in a circle around the North Star.

Among the constellations that are always above your horizon, if you live as far north as Chicago, are Ursa Major, Ursa Minor, and Cassiopeia. If you were at the North Pole, none of the stars you could see would rise or set.

The picture on page 28 was taken by keeping a camera pointed toward the North Star for an hour. The streaks of light were made by the North Star and the stars near it. Sometimes the seeming movement of the stars that do not rise and set is called the *circumpolar whirl.*

Star Dwarfs and Star Giants

In 1939 an American astronomer studied, through a huge new telescope, the star Wolf 457. He found that this star is very small as compared with most stars. It is not much, if any, larger than the earth. But there is several hundred thousand times as much material in it as there is in the earth. It is small simply because the particles of material in it are packed closely together. They are packed so closely that,

if a ball of the material the size of a golf ball could be brought to the earth, it would weigh several thousand tons. It would weigh so much that the earth could not hold it up. It would fall through the solid rock of the earth just as a real golf ball falls through air. Even a ball of the material the size of a pea would be so heavy that no person on earth could lift it. In fact, it would weigh so much that no automobile truck ever made would be strong enough to haul it from place to place.

Wolf 457 belongs to the class of stars which astronomers call *white dwarfs*. All white dwarfs are much smaller than our sun, although some of them are larger than the earth. The particles in all of them are closely packed together, and all the white dwarfs are white-hot. They are far hotter than the sun. The temperature in the center of the sun is supposed to be about 20 million degrees Fahrenheit. The centers of the white dwarfs are thought to be ten or twenty or even fifty times as hot.

Sirius, the brightest star in the sky, is a double star. Its companion is a white dwarf. So far as anyone knows, the companion of Sirius is our nearest white-dwarf neighbor. Sirius and its white-dwarf companion are no match for each other in size. The white dwarf is about thirty times as large as the earth, whereas Sirius is several times as large as the sun.

One white-dwarf star has as a companion a far larger star than Sirius. Its companion is the star Omicron Ceti (om'i-kron sē'tī). Omicron Ceti is one of the stars which astronomers call *giant stars*. This giant star is so large that, if it were hollow, 30 million suns or 30 million million earths could be packed inside it. Omicron Ceti and its white-dwarf companion are somewhat like a whale and a minnow together.

The Pleiades
Courtesy of Lick Observatory

There are other star giants like Omicron Ceti. One of the best known of them is Betelgeuse, the bright, reddish star in the constellation of Orion. Betelgeuse is about 25 million times as large as the sun. Antares, the bright, reddish star in Scorpio, is still larger. It is 70 million times as large as the sun.

Of course, all stars are giants compared with a house or a mountain or a meteor. Most of them are giants compared with the earth. The stars which astronomers call giants are giants compared with the sun and with most other stars.

Perhaps it will help you picture the size of the giant stars if you imagine putting one of them in the center of our solar system in place of the sun. If the center of Betelgeuse, for example, were put where the center of the sun is, its outside edge would be out beyond the earth's path, or orbit.

The giant stars are not nearly so hot as the white dwarfs. The temperature at the center of a giant may not be more than a million or two degrees. The material in the giants is not packed together so closely as in the dwarfs, either. It is not even packed so closely as it is in the sun. Although Betelgeuse is 25 million times as large as the sun, it has only about 40 times as much material in it.

None of the giants is a white or a bluish-white star. Most of them are red, but a few are yellow. They are not hot enough to be white or bluish-white. It is possible, you see, to tell something about the

Side View of a Spiral Nebula
Courtesy of Yerkes Observatory and the University of Chicago Press

temperature of a star from its color. The bluish-white stars are the hottest stars. Then, in order, come the white stars, the yellow stars, and the red stars. You are sure to know that iron, if it is heated in a furnace, becomes red-hot before it becomes white-hot. It should not be hard for you to understand, then, that stars of different temperatures are different colors.

We have no very close giant neighbor. Betelgeuse is 300 light-years away, and most of the giants are even farther away.

Most stars are neither giants nor white dwarfs. About eight-tenths of the stars are medium-sized stars. Our sun belongs to the great group of medium-sized stars.

Novae

Nearly four hundred years ago a Danish boy named Tycho Brahe decided that he wished to be an astronomer. Against the advice of his family, he studied astronomy at the university to which he was sent when he was eleven years old. After he finished his work at the university, he spent several years at various observatories in Europe.

When Tycho was twenty-four years old, his father died, and Tycho went back to Denmark. He lived with an uncle. This uncle was interested in chemistry. In those days chemistry was chiefly a search for a way of changing other metals into gold. Tycho, too, became interested in chemistry, and his uncle gave him a small building for a laboratory. Day after day Tycho worked there, often with his uncle.

Horsehead Nebula in Orion
Courtesy of Mount Wilson Observatory

One night as Tycho was walking home to supper, he happened to look up at the constellation of Cassiopeia. He saw there a very brilliant new star. At first he decided that there must be something seriously wrong with his eyes. Then he found that other people could see the new star, too. Tycho watched the star night after night. He forgot all about his chemistry. He was not the first person to see the new star, but he was the first person to watch it carefully and to try to work out some explanation for it.

When he began watching it, the star was as brilliant as Venus is at its brightest. After a few weeks it began to fade, and within a year and a half it was too dim to be seen without a telescope. Tycho published the records he had kept of it and his ideas about it in a book called *De Nova Stella.* The name of the book is in Latin, for Latin was the language of the scholars of Europe when Tycho lived. The words mean "about the new star." Tycho Brahe never went back to chemistry. He went on with his study of the stars until he became one of the greatest astronomers of all time.

Scientists now call such stars as the one Tycho Brahe saw in Cassiopeia *novae,* or "temporary stars." *Nova* means "new," as you can tell from the title of Tycho Brahe's book. Strangely enough, the star that started Tycho on his way to becoming one of the world's most famous astronomers was the brightest "new" star in all the history of astronomy.

Novae are not uncommon. Usually at least one "new" star is found every year. There was a very bright one in 1918. Novae are not really new stars. They are stars that suddenly become very, very much brighter than they were before. Scientists believe that they become brighter because they throw off a gaseous shell. Later these stars always fade. They may become very dim.

Of course, the explosion which made the "new" star Tycho Brahe saw did not take place the night he first saw the star. It had taken place many, many years before. Tycho Brahe did not see it until the light from it had had time to travel the many trillions of miles to the earth.

A Part of the Milky Way

Courtesy of Yerkes Observatory and the University of Chicago Press

Our Star City

As you have already been told, our sun is one of the stars in a great star city—a star city made up of at least 40,000 million stars. All the separate stars we can see when we look up at the sky are members of this great star city.

Our star city is often called the *Galaxy* or the *Milky Way Galaxy*. "Galaxy" comes from a Greek word meaning "milk." Whether we call it the Galaxy or the Milky Way Galaxy, then, our star city gets its name from the Milky Way.

You are almost sure to have seen the Milky Way. It is a band of light which stretches across the sky. It can best be seen on a clear, moonless night in midsummer or midwinter.

This band of light has, in many languages, a name which means "milky way." The Mexicans call it, instead, "the little white sister of the many-colored rainbow." If you followed this "white sister of the rainbow" hoping to find a pot of gold at the end of it, you would find that it has no end. It is a great circle of light.

People of olden times were much puzzled by the Milky Way. As soon as the famous scientist Galileo turned his telescope toward it about three hundred years ago, the puzzle was solved. His telescope showed clearly that the band of light comes from an enormous number of distant stars. They are too far away to be seen separately without a telescope.

No matter toward what part of the sky a telescope is turned, great numbers of stars that are hidden to our eyes come into view. Many more stars can be seen in the direction of the Milky Way, however, than in any other direction. When you know about the shape of the star city in which we live, the reason is easy to understand.

Our star city is shaped somewhat like a bun much flattened around the edges. If you were to look at it edgewise from somewhere far out in space, it would look much as the star city in the picture on page 22 looks.

To picture the position of the sun in our star city, imagine slicing a flattened bun into halves. Then imagine putting a tiny poppy seed on one of the halves about halfway between the center and the outer rim. Imagine, too, putting an even smaller seed close to the poppy seed. Finally, imagine putting the two halves of the bun together again. The poppy seed stands for the sun, and the smaller seed for the earth.

When you are looking toward the Milky Way, you are looking toward the rim of the star city. There are more stars in that direction than in any other, just as there is more bread between the tiny seed and the rim of the bun than there is in other directions.

The picture on page 25 is a picture of part of the Milky Way. Would counting the separate stars shown be easy?

The stars which make up our star city are not standing still. Instead, they are whirling about the center of the "city." Our sun is traveling just as the other stars of the Galaxy are. It is moving about 200 miles a second, and, of course, it is carrying the earth along with it. Even at the tremendous speed at which it is going, however, it needs two or three hundred million years to make its journey around the center of the Galaxy. It is hard for us to imagine that the sun has probably made this journey many times.

Ring Nebula in Lyra

Nebulae

If you look at the middle star in the sword of Orion through a small telescope, you will see that it is surrounded by a bright, greenish cloud. Through a big telescope this cloud looks as it does in the picture on page 29. Such a cloud is called a *nebula*. *Nebula* is the Latin word for "cloud."

There are many nebulae. Some of the stars in the Pleiades are surrounded by bright nebulae, as you can see from the picture on page 21. In the constellation of the Lyre there is a bright nebula shaped like a ring.

These bright nebulae are made of star dust or of gas. They would not be bright, astronomers think, if there were no stars near by to throw light on them.

Some nebulae are not bright. There are no bright stars very near them. The picture on page 23 shows a dark nebula. This nebula, like that on page 29, is in Orion. It is often called "The Horsehead Nebula" because it is supposed to look like the head of a horse. Dark nebulae shut off our view of stars which astronomers are sure are out beyond these nebulae.

Perhaps you have noticed when you have looked at the Milky Way on a summer evening that a dark streak divides it into two branches. There are various dark streaks and patches in the Milky Way. They are supposed to be dark nebulae. One dark patch is called "The Coal Sack."

Far Out in Space

The picture on this page shows a ball, or *globular cluster*, of stars in the constellation Hercules. There are hundreds of thousands of stars in the cluster. All together they give out two and a half million times as much light as the sun, but they are so far away that the whole cluster is not nearly so bright as Sirius or Betelgeuse or even the North Star.

Great Globular Cluster in Hercules

Without a telescope it can hardly be seen. It is a very faint, hazy patch of light.

There are over a hundred "balls" of stars like the one in the picture. All of them were discovered more than a hundred years ago. Even with the wonderful telescopes they have now, astronomers have not been able to find any others.

All of these balls of stars are very far away. Most of them are so far away that they cannot be seen at all without a telescope. It takes light more than 18,000 years to reach us from the very nearest one. The one in the picture is more than 30,000 light-years away.

Although the globular clusters of stars are very far away, they are still in our own star city. If you were making a model of our Galaxy, the globular clusters would be contained in your model.

You have already been told that there are other star cities like ours. You have been told, too, that some of these other galaxies are millions of light-years away.

When astronomers first saw these galaxies far out in space, they thought that they were nebulae somewhat like the Great Nebula of Orion (page 29). They are still often called "nebulae" or "spiral nebulae." Sometimes they are called simply "spirals." If you look again at the picture of the Great Nebula of Andromeda on page 2, you will not be surprised that astronomers first thought that it was just a cloud of gas or star dust. Now they know that it is made, instead, of millions of stars.

The Circumpolar Whirl

Courtesy of Yerkes Observatory and the University of Chicago Press

Notice the picture of the nebula on page 31. Do you see that it is much the same shape as the Great Nebula of Andromeda? Both of these star cities are shaped much like our own Galaxy.

To picture your place in the universe, think first of yourself on the earth. Then think of the earth as one of the smaller planets in the solar system. Next think of the whole solar system as being only a very, very small part of the Milky Way Galaxy. Finally, think of our Galaxy as being only one of more than three million galaxies. Perhaps new telescopes will show even more great star cities far out in space.

Are There Other Solar Systems?

Perhaps you have wondered as you thought of the stars whether any of them are the centers of solar systems like ours. No one knows. If any of the stars have planets circling around them, the planets are not bright enough to be seen even with our largest telescopes. Remember that we cannot see Pluto except with a very powerful telescope, and that the nearest star is about 7,000 times as far away as Pluto. What hope would there be of seeing planets so far away? Astronomers think that some of the distant suns may very well have solar systems like our own.

We are quite sure that no people like ourselves could live on any of the other planets in our own solar system. But somewhere out in space, circling around some distant stars, there may be other worlds like ours.

Great Gaseous Nebula in Orion

Courtesy of Yerkes Observatory and the University of Chicago Press

Star Myths

Why do some stars rise and set and others stay always above the horizon? Where do the stars go in the daytime? What holds up the sky? Such questions as these puzzled the people of long ago. The answers seem easy to us now, but they were not easy before there were any scientists. Since the people of long ago did not know how to find the right answers, they made up stories as answers. Such stories are called myths. As you have seen, the sky was a "picture-book" to the people of long ago. Their myths had to explain the puzzle of why the creatures they saw in the sky were there as well as the other puzzles about the stars.

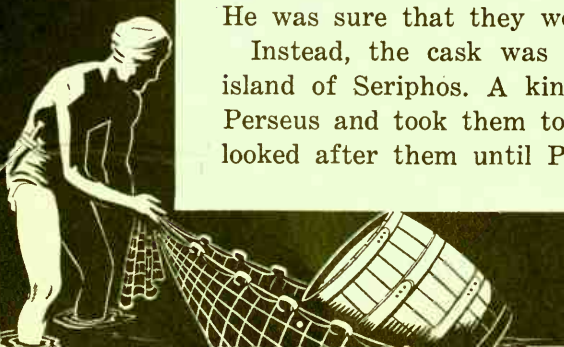
There are a great many star myths. All of them would fill many books the size of this book. Only one myth can be told here. Remember as you read it that myths were not fairy stories to the people of long ago. They were real attempts to explain what these people saw about them. They were the forerunners of the science of today.

The myth told on the following pages is about the four constellations Perseus (per'se-us), Cepheus (sē'fe-us), Cassiopeia (kas'i-o-pē'ya), and Andromeda (an-drom'e-da).

The Royal Family

Perseus is the hero of this story. He was the son of Danaë (dā'na-ē), the beautiful daughter of King Acrisius (a-cris'i-us) of Argos. Years before Perseus was born, Acrisius had been told by an oracle that he would be killed by his own grandson. When word was brought to Acrisius that his daughter had a baby son, he thought of a way of preventing the old prophecy from coming true. He ordered Danaë and Perseus to be put in an empty cask and thrown into the sea. He was sure that they would be drowned.

Instead, the cask was washed up on the shores of the island of Seriphos. A kindly fisherman rescued Danaë and Perseus and took them to his home. There he and his wife looked after them until Perseus grew to manhood.

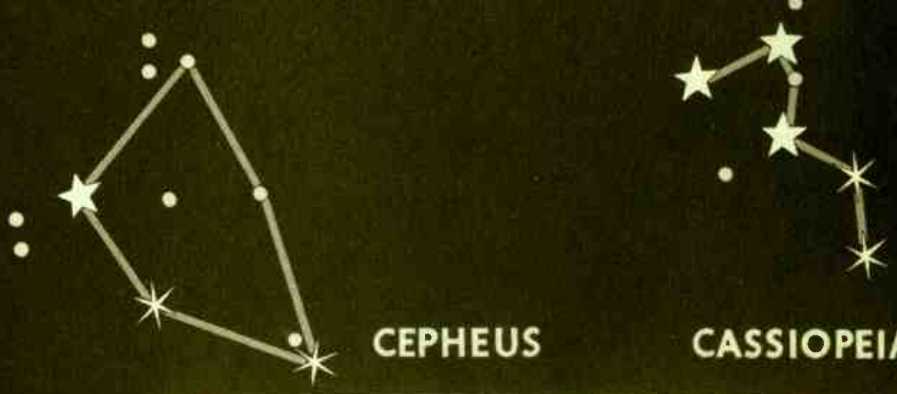


Spiral Nebula in Ursa Major
Courtesy of Yerkes Observatory and the University of Chicago Press

It happened that the kindly fisherman was the brother of Polydectes, the king of the island. While Perseus was growing up, Polydectes had seen Perseus and Danaë often. In time he fell in love with Danaë. He asked her again and again to marry him, but she was unwilling. At last, to punish her, he decided to send Perseus on a very dangerous errand.

He sent for Perseus and told him that he was to go kill Medusa and bring back her head. Medusa was one of the three Gorgons—monsters that were half woman and half dragon. Medusa had once been beautiful, but she had been rude to the goddess Minerva, and Minerva had punished her by changing her hair to snakes. Minerva had also decreed that anyone who looked at Medusa's face, which was still beautiful, should be turned to stone. You can see that Polydectes did not expect Perseus to bring back Medusa's head. He thought that Perseus would be changed to stone as soon as he came near Medusa.

Perseus started forth bravely on his errand. The gods were kind to him, and three of them gave him wonderful gifts. Pluto, the god of the underworld, gave him a helmet which made him invisible as soon as he put it on his head. Mercury, the messenger of the gods, gave him winged sandals. Minerva, the goddess of wisdom, gave him a shining shield.



Perseus' first task was to find out where Medusa and her sisters lived. The only people who knew were the Graeae (grē'ē), three old women who had only one eye among them. Far to the north Perseus had to go to find these old women.

When he finally came near them, they were quarreling about their one eye. The old woman who had the eye at the moment did not see him approach because he was wearing the helmet which Pluto had given him. Perseus knew that the old women would not want to tell their secret and that he would have to force them to do so. He slipped quietly in among them and took their eye as one of them was passing it to another. Then he spoke to them and promised to return the eye if they would tell him where to find Medusa. The old women were very eager to have their eye again and told him at once. Perseus kept his promise to return their eye, and then he started off to find Medusa.

For months he journeyed to the south. At last he was near the home of the Gorgons. He had been warned that he must not look at Medusa. Instead, he must use his shield as a mirror and look at her reflection in that. He found Medusa asleep. Holding his shield so that he could see her reflection clearly, he moved toward her. With one stroke of his sharp sword he cut off her head. Without looking at the head, he put it in a bag which he had brought with him. Then he hurried away on his winged sandals before the two sisters of Medusa could harm him. He hurried so fast that he stirred up great clouds of dust along his path. The dust made a broad, bright band across the sky.

Perseus flew high over land and sea back toward the island of Seriphos. As he flew over the great desert in Africa, drops of blood fell from Medusa's head and at once became poisonous snakes like the snakes on the head of Medusa.

In northern Africa he came upon Atlas, the giant who held the sky on his shoulders. Atlas had been holding up the sky so long that he was very tired. When Atlas found that Perseus had Medusa's head with him, he asked a strange favor. He asked Perseus to let him look at Medusa's head. Atlas was so tired that he wished to be changed to stone. Perseus let him have his wish. As Perseus left, he looked back and saw, not a huge giant with white hair, but a group of great mountains covered with snow.

Perseus had not gone far when he came upon a beautiful maiden chained to a rock on the shore of the sea. She was the princess Andromeda, daughter of King Cepheus and Queen Cassiopeia. Her mother was so proud of Andromeda's beauty that she had boasted that her daughter was fairer than the nymphs of the sea. A terrible sea monster had been sent to punish Cassiopeia. This monster was tearing to pieces the homes near the coast. The king and queen had consulted an oracle. The oracle had said that the monster would not leave unless Andromeda was sacrificed to him. Perseus reached the shore just after Andromeda had been chained to the rocks as a sacrifice to the monster.

When Perseus came close to Andromeda, he saw that she was looking in terror at the sea. Rising from it was the huge sea monster. He was lashing the sea to foam with his

tail as he came toward the beautiful princess. A terrible battle between Perseus and the monster began. Finally Perseus found time in the struggle to pull the head of Medusa from the bag. The sea monster at once turned into a ledge of black rock along the edge of the sea.

Perseus then cut Andromeda's chains and took her to her parents. King Cepheus offered Perseus half his kingdom, but Perseus wanted only one reward—to marry Andromeda. The king and queen gladly gave their consent.

Perseus took Andromeda back with him to the island of Seriphos. You can imagine that Polydectes was greatly surprised to see Perseus again. He refused to believe that Perseus had killed Medusa. He commanded Perseus to show him Medusa's head if he had it. Perseus finally did as he was commanded, and Polydectes and all his followers were changed to stone. The kindly fisherman became king of the island.

Perseus and Andromeda then persuaded Danaë to go with them to Argos. When they reached Argos, they found that Acrisius, Perseus' grandfather, had lost his throne. Perseus drove his grandfather's enemies from the kingdom and rescued his grandfather from the prison into which he had been thrown. Once more Acrisius was king.

The gods, however, had decreed that Acrisius was to be killed by his grandson, and nothing could change a decree of the gods. One day when Perseus was playing quoits, he accidentally killed his grandfather with one of the quoits. Perseus was overcome with grief. He became king of Argos, but he found no happiness in being king. He was constantly

reminded that he had killed his grandfather. Finally he exchanged his kingdom for a neighboring one. There he ruled long and well. When he died, the gods put him in the sky. With him in the sky they put Andromeda, King Cepheus, and Queen Cassiopeia. There the Royal Family can still be seen.

[This myth, as you see, explains how four of the northern constellations happen to be in the sky. It explains, too, why there are mountains in northern Africa so tall that they seem to hold up the sky, why there is a Milky Way (it is the dust along the path Perseus followed), why there is a great ledge of rock on the coast in a certain region of Africa, and why there are poisonous snakes in the African desert. The explanations the story gives seem very foolish to us now, but once, you should remember, people believed them.]

Star Superstitions

Astronomy, the study of the stars, is the oldest science. People began studying the heavenly bodies before they studied the plants and animals and rocks immediately around them. Even before there were any astronomers, there were astrologers—men who told the future from the stars. These ancient stargazers believed that the stars and the "wandering stars," or planets, had a great deal to do with people's lives. They thought, for example, that the positions of the planets among the stars when a child was born would determine whether the child would be strong or weak, happy or sad, rich or poor. Often in olden times an astrologer was called in to "read the stars" as soon as a child was born.

You have already seen that the stars have helped us greatly. Countless travelers on land and sea have told their directions from the stars. We set our clocks by the stars, too. Scientists know, however, that the stars have nothing to do with our fortunes. But, in spite of all that scientists have found out, there are still astrologers. Books on astrology are still being sold, and radio talks on astrology are common.

There is no such thing as a lucky or an unlucky planet or star. Any idea that there is belongs back in the days when people believed in dragons and sea monsters and thought that the earth was flat. If anyone ever wishes to read your fortune from the stars, listen if you like, but remember that telling a person's fortune from the stars is just as foolish as telling it from a pack of cards or the leaves in a teacup.

See for Yourself

1. Find out from a star map how many first-magnitude stars will be visible early tonight if the sky is clear. Try to find these stars in the sky.

2. On a star map find at least five constellations that will be visible early tonight if the sky is clear. Try to find these constellations in the sky.

3. Punch holes in a sheet of black paper to show the positions of the chief stars in some constellation. Arrange a way of making the light from a window or a flashlight shine through the holes in the paper so that the constellation looks somewhat as it looks in the sky.

4. If you are far enough to the north in the United States, all the stars of the Big Dipper are always above the horizon. But in a large part of the country some of the stars of the Dipper are sometimes below the horizon. Look for the Big Dipper early tonight if the sky is clear. How many of the seven bright stars can you see?

5. Visit a planetarium if there is one near you.

6. Make a clay model of the Milky Way Galaxy. Cut it in two horizontally. Put two tiny balls in the proper places to stand for the sun and earth.

Cover by FREDERICK F. SEYFARTH


RGO
PEGASUS
AURIGA
Spica
Capella